Estimates for Fish Passage Design Flows in Eastern Washington: The Contributing HUC6 Model

By

Erik R. Rowland[1], Rollin H. Hotchkiss[2], Michael E. Barber[3]

[1]Northwest Hydraulic Consultants,
Tukwila, WA 98188-3418
[2]Department of Civil and Environmental Engineering,
Washington State University,
Pullman, WA 99164-2910
[3]State of Washington Water Research Center,
Washington State University,
Pullman, WA 99164-3002

Introduction

A recent study was conducted in order to provide a methodology for predicting the fish passage design flows at ungaged locations in Eastern Washington. At the request of the Washington Department of Fish and Wildlife, this document summarizes the approach in sufficient detail as to allow practitioners to apply the model. Additional information concerning the approach can be found in the Journal of Hydrology paper by Rowland et al. (2003). Complete details of the model can be obtained from E. Rowland's Masters Thesis "Predicting Fish Passage Design Flows at Ungaged Streams in Eastern Washington", Department of Civil and Environmental Engineering, Washington State University (2001).

Previous methods of predicting flows at ungaged locations typically incorporated the use of regional models and equations developed by regression analysis. To avoid the complication of defining regions and estimating equation parameters, Washington State University (WSU) has developed a new approach, termed the Contributing-HUC6 model. Development of this model involves two major components; (1) defining a fish passage design flow and (2) developing a predictive model for ungaged streams.

Fish Passage Design Flow

Interpretations of Washington State Administrative Code 220-110-070 have led to the development of a design flow criteria based on the premise of allowable fish delay time. The allowable fish delay concept begins by defining the length of critical fish migration window to be one month. Applying the 10% exceedence flow concept to a migration window of one month means that the allowable number of days not passable is 10% of 30 days or 3 days. This means that for a design flow that is not exceeded more than 10% of the time, the 4th highest mean daily flow becomes the design flow.

Combining this concept with allowable fish delay time during the migration window, means that fish should not be delayed any more than 3 days at a time during their natural migration. Applying this criterion to a water year defines the design flow as the highest flow occurring in each water year that is equaled or exceeded by the previous 3 days. This provides one value for each water year. These annual flows are then averaged, providing a "mean annual fish passage design flow" or "4-day fish passage flow," termed Q_{FP4}.

This procedure was used to define Q_{FP4} for 64 United States Geological Survey (USGS) continuous record gages deemed to have a sufficient period of record for analysis. The design flows for each gage were then divided by the corresponding watershed areas to establish a design flow per unit area, Q_{FP4}/A.

Contributing HUC6 Method

The next aspect of this model is to assign a discharge per unit area to predefined subwatersheds in Eastern Washington. These subwatersheds are each given a numerical designation based on a 6th field Hydrologic Unit Code (HUC) and are more commonly referred to by the acronym 6th field HUC, or HUC6. The HUC6s found in Eastern Washington range in size from 3 to 287 mi^2, with a mean area of 33 mi^2.

Geographical Information Systems (GIS) techniques were used to analyze spatial data corresponding to these HUCs and the USGS gages used in the model. Much of this spatial data was obtained from the Interior Columbia Basin Ecosystem Management

Project (ICBEMP). This information consisted of spatial boundaries of HUCs, regions of known fish presence, digital elevation maps (DEMs), and mean annual precipitation. The boundaries of USGS watersheds used in the model were obtained from the USGS (Kresch, 2000). This information was analyzed in ArcView GIS to determine mean annual precipitation and mean elevation for USGS watersheds and HUCs (ESRI, 1999).

Larger basins comprised of many 6th field HUCs all draining to the same point are termed 4th field HUCs. These 4th field HUCs are commonly used to define regions for estimation of design flows, (Sumioka et al., 1998; Kresch, 1999; Powers and Saunders, 1996). Four regions in Eastern Washington were defined using clustering techniques based on mean annual precipitation, mean elevation, and mean water stress index for these 4th field HUCs.

The next step was to find the USGS watersheds that most closely match each 6th Field HUC based on similarity between basin characteristics. To explain this procedure consider one HUC6 and all of USGS gauges in one of the previously defined regions. A dissimilarity matrix was formed describing the Euclidean "distance" between the HUC6 and all of the USGS gauges within the region. The USGS gauges having the lowest distance values are those that most closely match the HUC6 by basin characteristics. This procedure was then repeated for every HUC6 within each region, providing a ranking of USGS gauges based on similarity of basin characteristics for every HUC6 in the model.

A discharge per unit area, Q_{FP4}/A, is then assigned to each HUC6 based on the values of the USGS gauges determined to be most similar to the HUC6. Two additional concepts are used to do this, a cutoff criterion and weighting method. The first concept defines a cutoff point for the number of gauges to include in the estimation of Q_{FP4}/A for the HUC6. Once the optimum number of gauges to include is determined their corresponding values of Q_{FP4}/A are weighted according to their dissimilarity distance and assigned to the each HUC6.

Overview of Design Procedure

Determining the fish passage design flow at any site, ungaged or gaged, requires the designer to follow 5 simple steps.

Scenario 1: GIS approach

1.) Delineate the watershed using USGS Quadrangle or other appropriate map.
2.) Determine the latitude and longitude for the downstream and upstream extents of the delineated basin.
3.) Using ArcExplorer (free software available from ESRI; http://www.esri.com/) or another Geographical Information Systems (GIS) application and the HUC6 shapefile provided, locate the HUC6(s) that your stream lies within.
4.) If the stream lies entirely within one HUC6 (determine this by comparing the latitude and longitude coordinates for the delineated basin to those of the HUC6s in the GIS shapefile) multiply the delineated basin area with the design flow for the HUC6 provided in the shapefile. This is the design flow (Q_{FP4}) the site.
    Hints: Once you located the HUC6 using the latitude and longitude coordinates, use the identify tool in ArcExplorer to determine the basin attributes. The fish passage "design flow" (in units of cfs/sqmi)

for a given HUC6 is defined with the attribute label "Q_cfs_sqmi". The basin area (in units of sqmi) for that entire HUC6 is defined with the attribute "Area_sqmi". See Figure 1.

5.) If the delineated basin encompasses more than one HUC6, it will likely fit the following scenario. The most upstream HUC6(s) will be totally encompassed within your delineated basin "termed the Upper Basin HUC6(s)" and the most downstream HUC6 will have the remaining area "termed the Lower Basin HUC6". To determine the design flow for this scenario:
   a. Multiply the entire "basin area" by the "design flow" in each of the HUC6(s) that are totally encompassed in the delineated basin, call this the "Upper Basin Contributing HUC6 Design Flow".
   b. Subtract the total basin area for the Upper Basin HUC6(s) from the total delineated basin area, this is the basin area within the lower HUC6.
   c. Multiply this remaining basin area by the "design flow" for the corresponding HUC6, call this the "Lower Basin Contributing HUC6 Design Flow".
   d. Add all of the Contributing HUC6 Design flows together to determine the total fish passage design flow at your site.

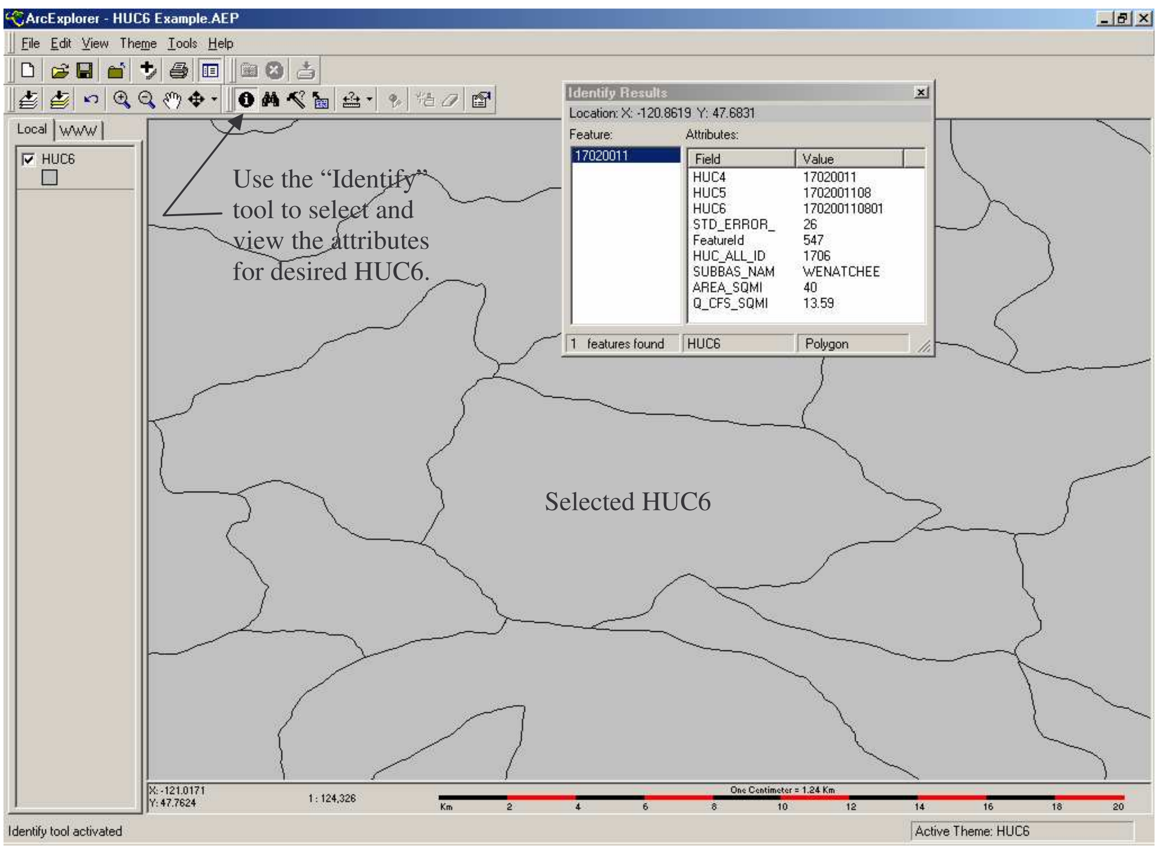

Figure 1. Using ArcExplorer to determine HUC6 attributes

Scenario 2: Paper Map Approach

1) Delineate the watershed using USGS Quadrangle or other appropriate map.
2) Determine the latitude and longitude for the downstream and upstream extents of the delineated basin.
3) Using the Map Region index map, identify which regional map the delineated basin is located on.
4) Determine if the stream lies entirely within one HUC6 (determine this by comparing the latitude and longitude coordinates for the delineated basin to those of the HUC6s on the appropriate map identified in Step 3). If the delineated basin is entirely within one HUC6, multiply the delineated basin area with the design flow for the HUC6 provided on the map. This is the design flow at the site.
5) If the delineated basin encompasses more than one HUC6, it is best to follow the steps outlined in the Step 5 of the GIS approach.

References:

1. Environmental Systems Research Institute (ESRI), Inc., 1997, ArcExplorer GIS, Version 2.0.
2. Interior Colmbia Basin Ecosystem Management Project, 2000, http://www.icbemp.gov accessed January 2000.
3. Kresch, D. L., 2000, Unpublished data
4. Powers, P., and C. Saunders, 1996, "Fish Passage Design Flows for Ungaged Catchments in Washington". Washington Department of Fish and Wildlife. http://www.wa.gov/wdfw/hab/engineer/cm/appc.htm. Accessed July 7, 2000.
5. Rowland, E. R. 2001, "Predicting Fish Passage Design Flows in at Ungaged Streams Eastern Washington", MS Thesis, Department of Civil and Environmental Engineering, Washington State University, Pullman, WA.
6. Rowland, E.R., R.H. Hotchkiss, and M.E. Barber, 2003, "Predicting fish passage design flows at ungaged streams in eastern Washington," Journal of Hydrology, V. 273, pp 177-187.
7. Sumioka, S.S., D.L. Kresch, and K.D. Kasnick, 1998, "Magnitude and Frequency of Floods in Washington," *Water Resources Investigations Report 97-4277, U. S. Geological Survey.*
8. Washington State Administrative Code 220-110-070. http://www.wa.gov.wdfw.hab.engineer/w2201170.htm. Accessed February 12, 2000.